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PREDATION BY THE CRAB, *CANCER OREGONENSIS* DANA, INSIDE OYSTER TRAYS

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ABSTRACT *Cancer oregonensis* is a predator of sub-market size oysters (*Crassostrea gigas*). Crabs enter oyster trays as megalops larvae between May and October, and attain a carapace width (CW) of 30 mm within a year. Despite its small size, *Cancer oregonensis* has powerful chelae; molar teeth and sharp tips are well adapted for crushing and puncturing oysters. In laboratory experiments the largest *C. oregonensis* (43 mm CW) was able to open market size oysters larger than 60 mm in length, while even a 20 mm wide crab consumed oysters 30 mm in length. Medium size crabs (20–35 mm CW) consumed an average of one young oyster (20–40 mm in length) per day.

A field experiment was set up in which 15 trays, each containing 315 ± 23 seed oysters, received 5, 2 or 0 newly settled *C. oregonensis*. Ten months later the average survival of oysters in the two crab treatments was 63% and 69% versus 90% for the control treatment. We recommend that crabs be manually removed during sorting operations.

KEY WORDS: crab, oyster culture, predation, *Cancer oregonensis*, *Crassostrea gigas*

INTRODUCTION

Crabs have been identified as major predators in shellfish culture on the shores bordering the Atlantic and the Gulf of Mexico (Menzel and Hopkins 1955, Parsons 1974, Walne and Davies 1977, Dare et al. 1983). Quayle (1988) recognized five species of Northeastern Pacific crabs as potential predators on the Pacific oyster, *Crassostrea gigas* (Thunberg): *Hemigrapsus nudis* (Dana), *Hemigrapsus oregonensis* (Dana), *Cancer magister* (Dana), *Cancer productus* (Randall) and *Cancer gracilis* (Dana). We now add *Cancer oregonensis* (Dana) to this list. While the crabs listed by Quayle (1988) primarily attack newly-planted oysters on the seabed, *C. oregonensis* feeds on a wide size range of oysters inside suspended trays.

Cancer oregonensis is found in the subtidal and low intertidal zones from the Bering Sea to Santa Barbara, California (Hart 1982). *Cancer oregonensis* is a small crab, attaining a maximum carapace width (CW) of 45 mm (Morris et al. 1980). Megalops larvae settle in interstitial habitats such as rock crevices, mussel beds, barnacle patches, kelp hold-fasts, bumper tires on floating docks, and oyster trays (Hart 1982, Orensanz and Gallucci 1988, personal observation). While larger *Cancer* species leave their nursery habitats as adults, *C. oregonensis* remain in these refuge-rich habitats their entire life (Orensanz and Gallucci 1988). *Cancer oregonenesis* is an opportunistic forager, feeding on barnacles, snails, bivalves, worms and algae (Knudsen 1964, Behrens Yamada, personal observation). Peak settlement of megalops larvae occurs during late spring and early summer (Jamieson and Phillips 1988, Lough 1975). Growth is rapid with some females attaining sexual maturity by the fall, just a few months after settlement (Orensanz and Gallucci 1988).

The small size of *C. oregonensis* megalops (2 mm CW; DeBrosse et al. 1989) allows them to enter oyster trays through the 6 mm holes provided for water circulation. Tray-raised oysters are thinner-shelled, and thus more susceptible to crab predators than intertidally raised oysters (C. Sanford, Innovative Aquaculture Products Ltd., Lasqueti Island, British Columbia, personal communication). Of all the crab species that settle inside oyster crabs, *C. oregonensis* has the most powerful chelae for its size (Lawton and Elner 1985, Behrens *et al.*, in preparation). With stout molar teeth on the occlusal surfaces and pointed tips, the chelae appear well adapted for crushing and puncturing growing oyster (Figure 1). *C. oregonensis* is common at oyster farms off the west coast of Vancouver Island, in the northern Hood Canal, northern Puget Sound and in the Strait of Georgia where salinity remains high throughout the year. Oyster growers from these areas report predation rates on young oysters exceeding 40% and as high and 90%.

The objectives of this study were:

1) To determine the maximum size at which Pacific oysters are vulnerable to *C. oregonensis* of a given size.
2) To determine the feeding rates of these crabs on oysters in the laboratory.
3) To quantify predation damage of known densities of crabs inside oyster trays.
4) To make recommendations for crab control.

MATERIALS AND METHODS

1) Critical Size of Oysters

Laboratory trials were set up to determine the largest oyster a given size *C. oregonensis* could crush. Crabs and oysters were obtained from Westcott Bay Sea Farms, San Juan Island, Washington and transported to Oregon State University where they were kept in recirculating sea water at 14°C with 12 hour light:dark cycle. Sixteen crabs of either sex, ranging from 11–43 mm CW, were placed inside individual plastic sandwich boxes (5 × 15 × 15 cm) with mesh sides to allow for water circulation. Four single oysters ranging from 12 to 40 mm length were offered to each crab. Consumed oysters were replaced by slightly larger ones, while non-feeding crabs received oysters of a smaller size range. Containers were monitored three times a week from February 11 to March 6, 1991. Feeding trials were repeated with 17 fresh crabs from April 10 to May 28, 1991. All feeding crabs (N = 28) were sexed and the average of the two largest oyster eaten per crab was plotted against crab CW.

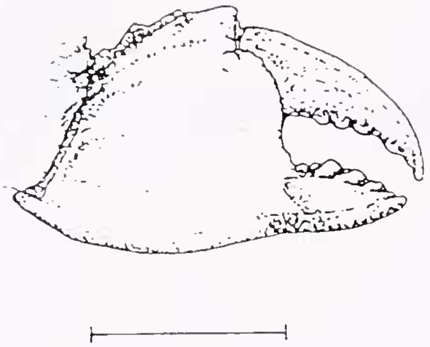

Figure 1. Right cheliped of *Cancer oregonensis* (32 mm carapace width). Scale bar = 10 mm.

2) Laboratory Feeding Rates

Feeding rates of crabs were determined in water tables with an open sea water system at the University of Washington Friday Harbor Laboratories, and in a re-circulating sea water system at Oregon State University (Table 1).

In a preliminary trial, 16 large crabs (30–40 cm CW) of either sex and 60 oysters ranging from 27 to 40 mm length were introduced into a sea water table (150 × 150 × 20 cm; water temperature = 14°C) at Friday Harbor Laboratories and covered with a sheet of black plastic on August 28, 1990. The number of oysters eaten in the first 9 hours was noted. Fifty more live oysters were then added to the water table and the number of oysters eaten in the subsequent 20 hours was determined.

In the next trial, 5 small crabs (19 to 28 mm CW) and 10 small oysters (21–36 mm in length) were introduced into each of 5 large plastic boxes (21 × 21 × 9 cm) in a water table (water temperature of 15° C) at Friday Harbor Laboratories. Boxes were checked daily for 5 days and consumed oysters replaced.

The subsequent trial was carried out with the same crabs at two locations. At Friday Harbor 32 crabs ranging from 17 to 44 mm CW were placed inside individual plastic sandwich boxes containing 4 oysters each. Crabs smaller than 30 mm received oysters ranging from 15 to 40 mm in length, while larger crabs received 30 to 50 mm oysters. Boxes were kept in a water table at 15°C. Feeding boxes were checked every day from June 24 to June 28 1991 and consumed oysters replaced. On June 29 all feeding crabs were transported inside a cooler to Oregon State University. For the next 3 days crabs were fed cracked oysters and allowed to acclimate to the new conditions (water temperature = 16°C). Feeding trials resumed July 3 and continued until July 18. This time the boxes were monitored every second day. Daily feeding rates were determined for each feeding crab.

3) Crab Predation Inside Oyster Trays

To assess the predation pressure of *C. oregonensis* on oysters under natural conditions, we set up an experiment inside oyster trays at Westcott Bay Sea Farms on August 29, 1991. Fifteen Mexican oyster trays (56 × 57 × 7.5 cm) each received 3 liters of seed oysters (mean number per tray = 315; standard deviation = ±23), ranging in length from 28 to 35 mm. Either 5, 2 or 0 juvenile *C. oregonensis* (10 to 20 mm CW) were added to each tray.

Survival of oysters, growth of oysters and crabs, and settlement of juvenile crabs were monitored on October 12, 1991, February 7, and June 22, 1992. An average daily consumption rate per crab was estimated for all 10 crab trays by taking the number of dead oysters (difference between the number of live oysters at the beginning and the end of the experiment), subtracting 31 (the average number of dead oysters in a control tray) and dividing by the mean number of crabs in a tray (total of initial number and final number divided by 2) and by 297 d. The arcsine transformation was used on percent oyster survival before performing ANOVA on treatment effect (Sokal and Rohlf 1981).

RESULTS

1) Critical Size of Oysters

The average length of the largest two oysters consumed by crabs of various CW is given in Fig. 2. No sex difference in crushing ability was detected. Since oysters vary in shape, length should not be interpreted as an absolute measure of critical size. Nevertheless, *Cancer oregonensis* of all sizes are able to crush and feed on oysters longer than their own carapace width. Thus, a crab of 20 mm carapace width can successfully attack oysters 30 mm in length, while the largest crab can open market size oysters (>60 mm).

2) Laboratory Feeding Rates

Over short time periods crabs are capable of consuming over 3 oysters (within their critical size range) per day. An average long-

TABLE 1.

Feeding rates of *Cancer oregonensis* in laboratory trials at Friday Harbor Labs (FHL) and Oregon State University (OSU).

Trial	Experim. Units	# crabs/unit	Crab CW (mm)	Oyster Length (mm)	Duration	Feeding Rate Mean	(#/day/crab) (SD)	Maximum
FHL 14°C	1 water table	16	30–40	27–40	9 h	5.5		
					20 h	2.0		
FHL 15°C	5 large boxes	5	19–28	21–36	5 d	0.62	(0.25)	1
FHL 15°C	19 boxes	1	17–29	15–40	4 d	1.06	(0.76)	4
	13 boxes	1	31–44	30–50	4 d	0.77	(0.68)	3
OSU 16°C	16 boxes	1	17–29	15–40	15 d	1.16	(0.50)	3
	9 boxes	1	31–44	30–50	15 d	0.99	(0.18)	3

For details on experimental design see text.

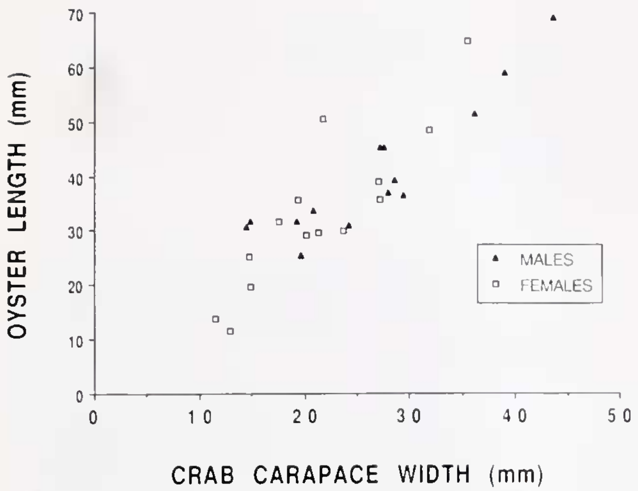

Figure 2. Average of two largest oysters crushed by crabs of various carapace width. No significant difference was found between male and female crabs.

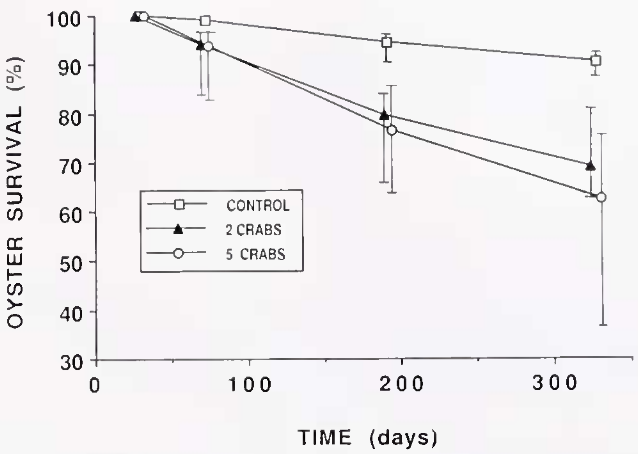

Figure 3. Mean survival rate (%) of seed oysters inside trays with and without crabs. The range of values are indicated by error bars.

term feeding rate of 1 oyster per day, however, is more realistic in that this rate includes data from molting crabs that ceased feeding for up to 6 d.

3) Crab Predation Inside Oyster Trays

Survival of experimental crabs inside oyster trays was 77% over the 297 days of the experiment. Since crabs died at various times throughout the year, no significant regression between number of surviving crabs and number of dead oysters was found. Their average carapace width was 23 mm in October, 26 mm in February and 30 mm in June. At termination of the experiment the oysters had attained an average length of 60 mm.

Cancer oregonensis open oysters by progressively chipping away at the shell margin or, more commonly, by puncturing the shell. Small, rapidly-growing oysters with fragile shells and thin lips are particularly vulnerable.

The average feeding rate of crabs inside the 10 oysters trays was estimated to be 0.09 (standard deviation = ±0.05) oysters per crab per day. This value is one order of magnitude lower than those observed in laboratory trials. One reason for this discrepancy is that throughout the field experiment, the average oyster was over twice the carapace width of the average crab.

Survival of oysters inside control trays was significantly greater than in trays containing an initial 2 or 5 crabs (ANOVA for arcsine transformed percentages: $F = 12.939$, d.f. $= 2$, $p < 0.001$) (Figure 3). Survival in control trays ranged from 88 to 93% while trays with crabs ranged from 37 to 81%.

Only 3 newly-settled juveniles entered the 15 trays between August 29 and October 12, while none were recovered in February. On June 22, eighteen newly-settled *Cancer oregonensis* (3–5 mm CW) were recovered.

DISCUSSION

Cancer oregonensis has the potential to be an important predator inside suspended oyster trays. Since tray-raised oysters are thin-shelled, they do not attain an absolute size refuge from these powerful crab predators as is the case for sea bottom-reared oysters on Atlantic shores. Eggleson (1990) and Elner and Lavoie (1983) found that American oysters (*Crassostrea virginica* (Gmelin)) larger than 30 mm in length were rarely opened by lobster (*Homarus americanus* (Milne-Edwards)), rock crab (*Cancer irroratus* (Say)) or blue crab (*Callinectes sapidus* (Rathbun)). The largest *C. oregonensis*, however, can open market size oysters over 60 mm in length, while even 20 mm CW crabs consume 30 mm length oysters.

At an average consumption rate of 0.1 oyster per day, five crab inside a tray could eat 120 oysters in the 8 mo during which the oysters are normally kept in trays. That represents a 40% reduction in oyster survival and profit. The winter and spring of 1992 were unusually mild, with oysters growing and surviving well. In years when oysters grow more slowly, crabs would gain a size advantage over the oysters and could cause more devastating effects than we measured.

Cancer oregonensis megalops larvae with a carapace width of 2 mm (Lough 1975) can easily enter the 6 mm diameter holes of Mexican oyster trays. Once inside, the larvae metamorphose into first stage crabs of 3 mm CW (Orensanz and Gallucci 1988, and personal observation). Oyster trays are ideal crab habitats, with abundant food and protection from predators such as the octopus. In addition to oysters, growing crabs can feed on fouling organisms such as algae, sponges, tunicates, sea cucumbers, gunnels, barnacles and mussels.

Settlement of *C. oregonensis* megalops larvae off the west coast of Vancouver Island occurs from April to August, with a peak abundance in late June (Jamieson and Phillips 1988). Our observations suggest that the settlement peak in 1991 occurred during late June, but that in June 1992 it occurred two weeks earlier. In our experimental oyster trays, we observed some newly settled *C. oregonensis* between late August and early October, none between October and February, and a moderate settlement during June 1992. While Lough (1975) reports some megalops larvae in Oregon plankton samples during the winter, the chance of a commercially important settlement to occur from October to April appears low.

Recommendations for Crab Control

Since *C. oregonensis* attack oysters larger than their own carapace width, and since newly-settled crabs become oyster predators within 3 months, crabs of all sizes should be removed from oyster trays. Growers at Skerry Bay on Lasqueti Island, use a freshwater bath to rid their oyster trays of sea stars and crab predators (C. Sanford, personal communication). *Cancer* crabs, are osmoconformers (Dehnel and Carefoot 1965) and are thus intolerant of low salinities. Smaller *C. oregonensis*, with higher surface area to volume ratios, would be especially susceptible to fresh water baths.

Growers at Westcott Bay Sea Farms manually remove larger crabs (>20 mm in CW) from their trays when oysters are sorted. They report an increase in the survivorship of young oysters since this predator control measure was started four years ago (B. Peoples, personal communication). Crab predation, however, remains a problem during the winter when oysters grow more slowly and trays are not checked as frequently. Since crabs continue to feed during the winter, a special effort should be made to rid trays of all crabs during the last oyster sorting operation in the fall.

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